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Part III

Water Resources Council

Synthetic Fuel Development for the Upper Missouri River Basin; Water Assessment

WATER RESOURCES COUNCIL

Synthetic Fuel Development for the Upper Missouri River Basin; Water Assessment

AGENCY: United States Water Resources Council.

ACTION: Notice of water assessment report for public review and comment.

SUMMARY: This notice incorporates the Water Assessment Report prepared by the Water Resources Council staff under provisions of Section 13(a) of the Federal Nonnuclear Energy Research and Development Act of 1974, as amended.

DATE: Comments on this report are due on or before January 27, 1981.

ADDRESS: Send comments to: Gerald D. Seinwill, Acting Director, U.S. Water Resources Council, 2120 L Street, NW., Washington, D.C. 20037.

FOR FURTHER INFORMATION CONTACT: Ronald L. Scullin, Staff Specialist, U.S. Water Resources Council, 2120 L Street, N.W., Washington, D.C. 20037. Phone: 202/254–6352.

Dated: October 24, 1980.

Gerald D. Seinwill,

Acting Director.

Table of Contents

Preface
National Energy Concerns
Water Resources Council's Water and Energy Program
Purpose of the Assessment
Conduct of the Assessment
Major Assumptions and Projections
Water Baseline
Energy Supply
Energy Development Patterns
Water Requirements for Synfuel Technologies
Major Findings
Water Requirements
Water Supply Availability
Water Supply Options
Other Findings
Groundwater
Runoff and Process Water
Hydroelectric Power Generation
Navigation
Community Infrastructure
Conclusion

Preface

The U.S. Water Resources Council (WRC) staff has prepared this report under the provisions of paragraph (a) of Section 13 of the Federal Nonnuclear Energy Research and Development Act of 1974, as amended. This report summarizes the results of an assessment of water requirements, water supply availability, and other water implications of synthetic fuel development in the Upper Missouri River Basin. Under a memorandum of agreement with WRC, the Missouri River Basin Commission conducted the regional assessment and published a regional report entitled "Upper Missouri River Basin: Water Availability Asssessment for Coal Technology Requirements," which serves as the principal basis for this report. Publication of this report in the **Federal Register** is mandated under the provisions of Section 13 to enable public review and comment during a 90-day period.

This summary highlights important aspects of the Upper Missouri regional assessment. Individuals or organizations that want to comment on the water and energy regional assessment should examine the *full technical report* entitles: Section 13(a) Water Assessment Report—Synthetic Fuel Development for the Upper Missouri River Basin.

Copies of the full report can be obtained from: Wanda Phelan, U.S. Water Resources Council, 2120 L Street, N.W., Washington, D.C. 20037, (202) 254–8290.

After the 90-day review period, the WRC staff will analyze the comments received and revise the report as appropriate. WRC will forward the comments, the WRC analysis, and the final water assessment report to the Secretary of Energy.

National Energy Concerns

On July 15, 1979, President Carter addressed the Nation regarding one of the most important problems confronting us—the energy crisis. Calling the "erosion of our confidence in the future" a "fundamental threat to American democracy," the President urged us to tackle the specific problem of energy as part of an effort to regain our national assurance. To give us "energy security," the President outlined various initiatives in his strategy to reduce our imports of foreign oil. A cornerstone of his energy policy was the commitment to develop alternative sources of fuel from American resources, especially our vast coal reserves. The President proposed a major program to accelerate development of technologies for synthetic fuels from coal, oil shale, and biomass. The program would produce the equivalent of 2 million barrels per day of substitutes for imported oil by the early 1990's. On June 30, 1980, the President signed the Energy Security Act, legislation designed to achieve this production goal.

Among the emerging technologies that could be used to exploit the Nation's coal resources are coal gasification (coal converted to gaseous products) and coal liquefaction (coal converted to liquid products). Judicious selection of research and development projects, pilot plants, and demonstration and commercial efforts will develop useful information on a variety of options to derive synthetic fuels from coal. The successful implementation of the emerging technologies ultimately will require the solution of complex technical, economic, social, and environmental issues. One important factor that will influence our ability to develop a basic level of synthetic fuels production is water.

Water Resources Council's Water and Energy Program

The Federal Nonnuclear Energy Research and Development Act of 1974 (P.L. 93–577, as amended) authorizes an extensive and accelerated program for research and development of nonnuclear energy technologies that will lead to full-scale commercialization. Within the Act, Congress expressed a strong concern about the water resources implications of new energy technologies. The Governing Principles of the Act state: "Any program for the development of a technology which may require significant consumptive use of water after the technology has reached the stage of commercial application shall include thorough consideration of the impacts of such technology and use on water resources . . . ." Subsection (a) of Section 13, the authorization for this report, provides that the U.S. Water Resources Council shall conduct water assessments of such nonnuclear energy technologies.

Water and energy assessments will help advance water resources planning and management strategies that ensure that water will be available for energy technology development and other beneficial uses. Section 13(a) assessments which are currently being conducted as part of the Water Resources Council's water and energy program include the water resources regions of Upper Colorado, Ohio, Pacific Northwest, Great Basin, California, Lower Colorado, Rio Grande and Texas-Gulf.

Purpose of the Assessment

The Upper Missouri River Basin, which comprises most of the Northern Great Plains, contains large deposits of coal that have been estimated at 165 billion tons (see Figure 1). Extraction of this resource has increased in recent years. With the continuing national problems of energy supplies and the current national emphasis on coal utilization, coal development is

expected to increase rapidly in the area. Because expanded development and conversion of coal resources in the Great Plains seems imminent, especially in light of the President's goals and the fact that the first full-scale commerical coal gasification plant soon will be constructed in Mercer County, N.D., the Water Resources Council conducted a regional water and energy assessment of the Upper Missouri Basin.

The purpose of the Upper Missouri assessment was to determine the availability of water to support certain hypothetical levels of synfuel development for three types of coal conversion technologies and to identify the effects that synfuel development could have on the water resources of the region. The three coal conversion technologies examined were:

- *High Btu Gasification*—The chemical and physical conversion of solid coal to methane gas. Methane has sufficient heat content (near 1,000 Btu/cubic foot) to be a pipeline quality substitute for natural gas.
- *Low Btu Gasification*—The chemical and physical conversion of solid coal to gas with heat value of 100–500 Btu per cubic foot. Low Btu gas is used for industrial purposes, including electric power generation.
- *Liquefaction*—The chemical and physical conversion of solid coal to produce liquid hydrocarbons. Synthetic crude oil is generally an intermediate if not the final product of the process.

Hypothetical unit size coal conversion plants were sited in reasonable locations in the assessment area. Actual synthetic fuel development may consist of partial, single, or multiple unit size conversion plants. For any of the conversion technologies, a unit size plant produces a synthetic fuel that has the energy equivalent of 250×10^9 Btu per day.

The assessment was not designed to address site-specific questions. Therefore, users of this report are cautioned not to interpret information as applicable to a specific site.

Conduct of the Assessment

The Missouri River Basin Commission (MRBC) staff provided study management for this assessment. The assessment was conducted by representatives from the States of Montana, Wyoming, North Dakota, and South Dakota and from Federal agencies using existing published and unpublished data and information. During early phases of the assessment, the Department of Energy (DOE) provided the MRBC with a technical report on coal technologies and their potential for development in the Upper Missouri Basin. The MRBC study manager was responsible for implementing the scope of work, coordinating the work effort among participants, reviewing hydrologic and engineering data, and preparing the draft and final regional report. Guidance was provided to the study manager by WRC and the MRBC Water and Energy Committee. The participating States were represented on this committee.

Contractual assistance on specific elements of the assessment was provided by the U.S. Bureau of Reclamation (now Water and Power Resources Service), U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Geological Survey, participating States, and consultants.

Major Assumptions and Projections

Figure 2 illustrates the Upper Missouri assessment area and its eight assessment subareas. The subarea boundaries represent a combination of political and hydrologic delineations.

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Fig. 1—Distribution of Coal Reserves

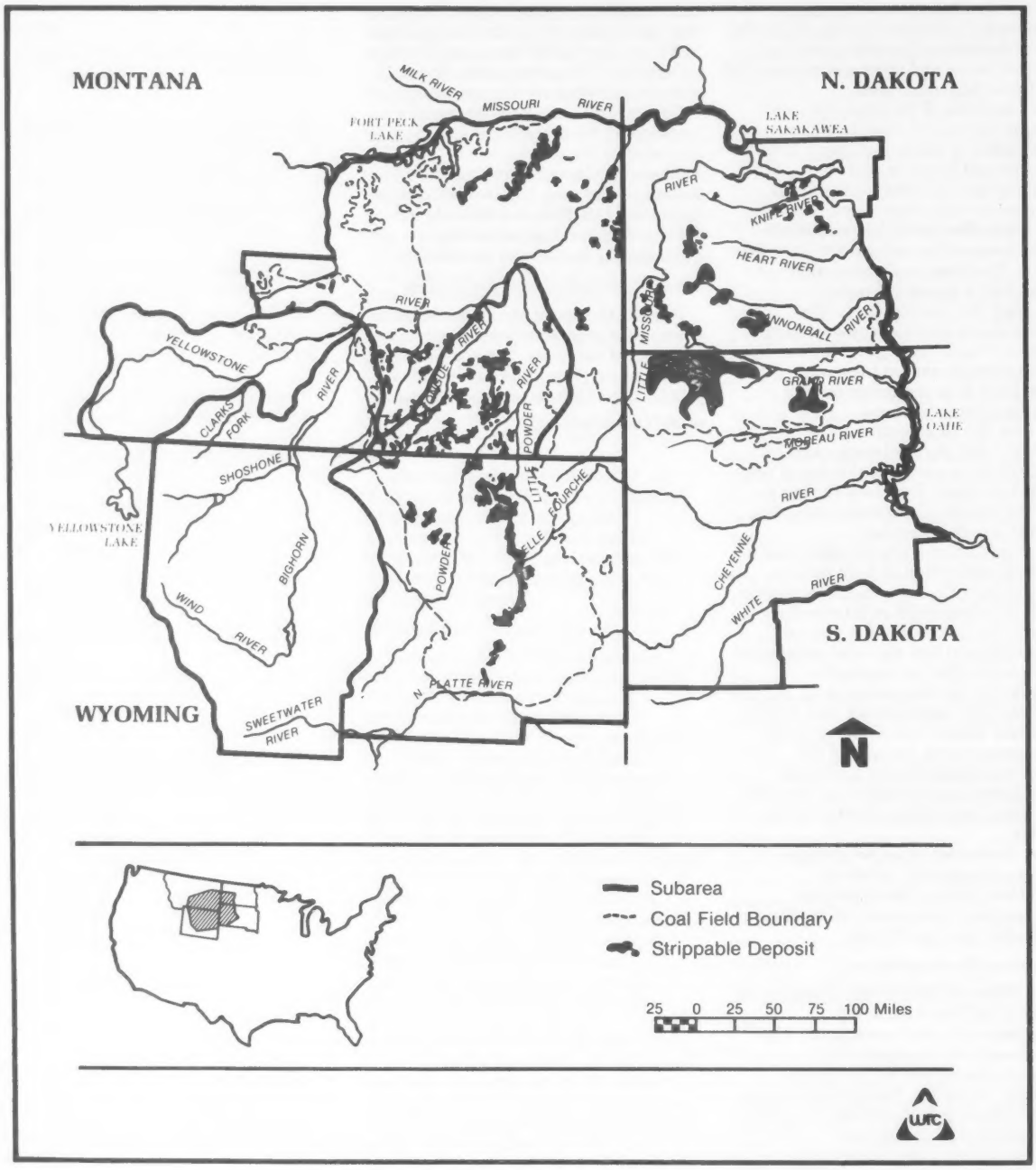
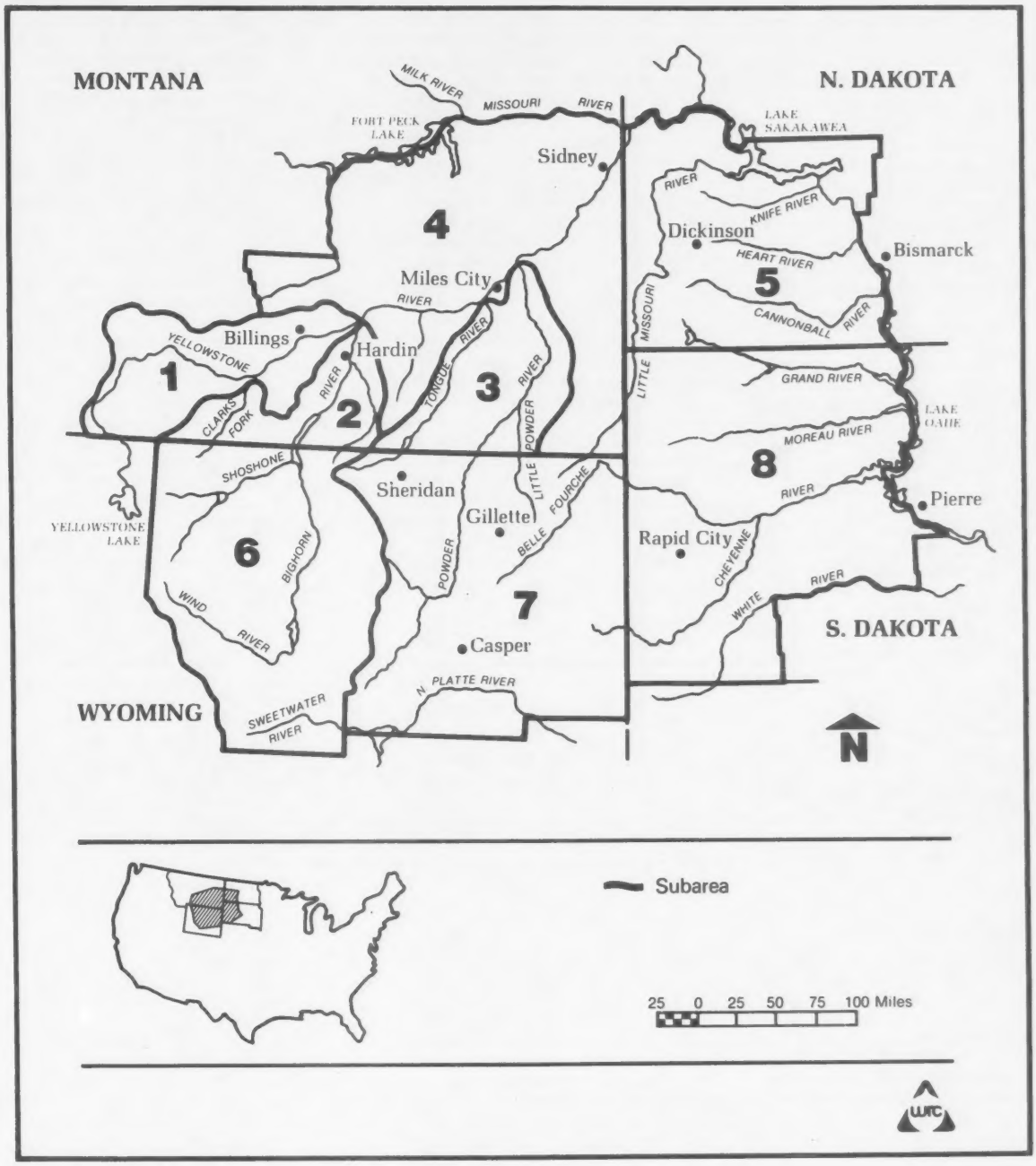


Fig. 2—Assessment Area with Subareas



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Water Baseline.—Current and projected levels of water uses, water requirements, water availability, and economic activity (including coal mining) were taken from the *Yellowstone River Basin and Adjacent Coal Area Level B Study* which was published by the Missouri River Basin Commission in 1978. This information forms the water resources baseline for 1975, 1985, and 2000 against which water supply availability for synthetic fuel development and associated effects were determined.

The recommended plan and the other recommendations in the Yellowstone Level B report are used as a guide to water and related land resources conservation and management in the Yellowstone River Basin and the adjacent coal areas. This study is updated through the MRBC's comprehensive, coordinated, joint planning process and the member States' ongoing water planning programs. The Upper Missouri assessment area is the same as that examined in the Level B study except for the addition of the area in western South Dakota.

An engineering consulting firm conducted water quality analysis for the Upper Missouri assessment. The potential effects of hypothetical levels of coal conversion development were studied to forecast possible water quality conditions for 1985 and 2000.

For the Upper Missouri assessment, total dissolved solids (TDS) was examined to indicate effects of synfuel development on water quality. Sulfates and acid mine drainage were not considered because the area's coal deposits contain a low concentration of sulfur.

Energy Supply.—Two hypothetical levels of synfuel development potential, the Base Case and the Accelerated Case, were assessed for the Upper Missouri River Basin for the years 1985 and 2000. The U.S. Department of Energy developed both cases to translate DOE's national energy demand and supply projections to the potential development in the assessment area. Estimates of annual energy generation from coal conversion technologies were also defined for the assessment area by DOE.

Both the Base and the Accelerated Cases were based on national consumption of 98 quads (quadrillion Btu) in 1985 and 143 quads in 2000. However, more recent DOE supply and demand studies suggest these levels of energy consumption may be high and that a level of 125 quads or less in 2000 is more likely.

The national demand projections are the same for both cases. However, the energy supply cases are predicated on different assumptions about synfuel development. The Accelerated Case assumes a more significant role for synfuel development in meeting the national energy needs than does the Base Case. For example, in comparison with the Base Case, the Accelerated Case assumes that synfuels would substitute for a greater portion of foreign imports and that they would be more likely to reduce extraction of domestic natural oil and gas resources. These assumptions are based on the relative success of synthetic fuels research and development programs, the degree of Federal assistance, and the speed of market penetration. The Accelerated Case also assumes an optimistic degree of success as measured by production costs and early market penetration of synthetic fuels. Further, the Accelerated Case assumes that market penetration would be stimulated by Federal loan guarantees and other economic incentives. Both cases were developed to show possible national energy supply and demand balances under hypothesized conditions that encompassed a reasonable range of synfuel development potential. Neither the Base nor the Accelerated Case is intended to predict a "most likely" or "intended" future.

Energy Development Patterns.—The DOE did not select the location of any individual synfuel plants or the mines that would supply them. Neither was there an attempt to select any particular process for a coal conversion technology as this was beyond the scope of this regional assessment. Rather, the Missouri River Basin Commission had the flexibility to hypothesize:

1. Candidate locations for energy plants, coal mines, and transmission systems, demographic development, and other support mechanisms in accordance with regional preferences and with consideration of available water, location of resources, demographic and transport/transmission patterns, existing plants, and similar factors.

2. The number and size of plants (including any preferred technology and process mix) best suited to meeting the regional energy supply projections and consistent with projected water resource conditions.

3. Location of the plants and estimates of total water requirements and availability of the preferred plant mix.

4. Required wastewater treatments for the preferred plant mix in order to meet applicable local, State and Federal water quality standards.

Using this flexibility, the MRBC selected reasonable development patterns for synfuel plants. Each hypothetical unit size coal conversion facility (i.e., one plant producing synthetic fuel with energy equivalent of 250×10^9 Btu per day) was sited with general regard to coal resources, water supplies, transportation, water quality, air pollution control, and land use. Site locations were approximated without the aid of detailed locational analysis. Table 1 shows how the hypothetical plants were distributed among the eight assessment subareas under Base Case development levels. In 1985, no synfuel plants were hypothesized for the Base Case. Table 2 shows how the hypothetical plants were distributed under the Accelerated Case.

The development patterns are not intended to represent proposed regional or State synthetic fuel development plans. Instead, they reflect one reasonable distribution of facilities in the area, based on existing information, for a hypothesized total level of development derived from a national analysis of energy supply and demand.

Water Requirements for Synfuel Technologies.—Estimated water requirements (i.e., consumption) for the three coal conversion technologies were based on theoretical calculations, small-scale experimental facilities, and other related information. As more process data and field experience are obtained from future operations of demonstration and full-scale commercial facilities, more accurate estimates can be prepared. The estimates assume recycling of water at the plant and no water discharged to receiving streams (i.e., zero discharge). Treated plant water would be recycled to supplement water supplies for conversion process water, wet cooling, and related activities.

Table 1.—*Synthetic Fuel Development Patterns: Base Case—1985 and 2000*

[Number of unit size plants]

Subarea and river basin/State	1985	2000			
		High Btu gasification	Low Btu gasification	Liquefaction	Total
1 Upper Yellowstone River in Montana	0	0	0	1	1
2 Bighorn River in Montana	0	0	0	0	0
3 Powder and Tongue Rivers in Montana	0	0	0	1	1
4 Lower Yellowstone River in Montana	0	2	0	2	4
5 Missouri River and tributaries in North Dakota	0	9	0	2	11
6 Bighorn River in Wyoming	0	0	0	0	0
7 Powder and Tongue Rivers in Wyoming	0	4	0	0	4
8 Missouri River and tributaries in South Dakota	0	0	0	0	0
Total	0	15	0	6	21

Table 2.—*Synthetic Fuel Development Patterns: Accelerated Case—1985 and 2000*

[Number of unit size plants]

Subarea and river basin/State	1985	2000			
	High Btu gasification	High Btu gasification	Low Btu gasification	Liquefaction	Total
1 Upper Yellowstone River in Montana	0	0	1	1	2
2 Bighorn River in Montana	0	0	0	0	0
3 Powder and Tongue Rivers in Montana	1	4	0	3	7
4 Lower Yellowstone River in Montana	0	1	0	1	2
5 Missouri River and tributaries in North Dakota	6	8	0	4	12
6 Bighorn River in Wyoming	0	0	0	0	0
7 Powder and Tongue Rivers in Wyoming	0	9	0	0	9
8 Missouri River and tributaries in South Dakota	0	0	1	0	1
Total	7	22	2	9	33

For this assessment, water requirements for coal conversion include water for conversion processes, wet cooling, and related facility operation. The estimated water requirements are wide ranging because of differences among individual process technologies, relationships to the type of coal used, varying efficiencies in cooling equipment, air and water pollution control, and facility design options.

The estimated ranges of water requirements for the three technologies assessed are presented in Table 3. These estimates represent the water to operate a unit size coal conversion plant at 90 percent capacity.

Table 3.—*Water Requirements for a Unit Size Plant for the Synfuel Technologies*

Technology	Water requirements (acre-feet per year)
High Btu gasification	5,960–14,030
Low Btu gasification	6,550
Liquefaction	4,700–7,800

The annual water requirement for synfuel development in the Base and Accelerated Cases are given in Table 4.

Overall, the Base Case would require an estimated 194,000 acre-feet of water per year by 2000. The Accelerated Case would require about 78,000 acre-feet per year by 1985 and about 276,000 acre-feet per year by 2000.

Table 4.—*Water Requirements by Synfuel Case—1985 and 2000*

[Acre-feet per year]

Subarea and river basin/State	Base Case		Accelerated case	
	1985	2000	1985	2000
1 Upper Yellowstone River in Montana	0	6,630	0	14,350
2 Bighorn River in Montana	0	0	0	0
3 Powder and Tongue Rivers in Montana	0	7,800	8,700	66,550
4 Lower Yellowstone River in Montana	0	33,160	0	16,580
5 Missouri River and tributaries in North Dakota	0	115,250	69,000	110,800
6 Bighorn River in Wyoming	0	0	0	0
7 Powder and Tongue Rivers in Wyoming	0	30,840	0	60,640
8 Missouri River and tributaries in South Dakota	0	0	0	6,550
Total [1]	0	194,000	78,000	276,000

[1] Rounded to nearest thousand acre-feet per year.

In addition to these water requirements, synfuel development would stimulate related water uses, referred to here as secondary water requirements. In this assessment, the secondary water uses examined were:

- water for coal mining and related land reclamation (coal for synfuel production)
- water for offsite thermal electric power generation (electricity to operate synfuel technologies)
- water for increased municipal water supplies (increased supplies to support population growth attendant with synfuel development)

Table 5 summarizes major water requirements associated with synfuel development. Water requirements for coal conversion are about 4 times secondary water requirements.

Table 5.—*Cumulative Water Requirements by Synfuel Case—1985 and 2000*

[Acre-feet per year]

Type of water use	Base case	Accelerated case	
	2000	1985	2000
Coal conversion	194,000	78,000	276,000
Secondary	53,000	20,000	74,000
Total	247,000	98,000	350,000

Major Findings

The following determinations were based on information gathered during the assessment.

- Water Requirements

For the year 2000, Base Case synfuels development at 1.1 million barrels per day oil equivalent would consume approximately 250,000 acre-feet of water annually while Accelerated Case synfuels development at 1.7 million barrels per day would consume approximately 350,000 acre-feet. Of these totals, about 200,000 and 276,000 acre-feet of water, respectively, would be consumed by the coal conversion technologies. The remaining 50,000 and 74,000 acre-feet would be consumed by supporting activities, such as goal mining and land reclamation, thermal electric power generation for plant operations, and municipal water supply associated with synfuel population growth.

- Water Supply Availability

Water supplies for synthetic fuels development will be controlled by a number of factors, including surface and groundwater resource conditions, the extent to which these resources have

been institutionally committed or allocated, and the extent to which instream uses would be affected by additional depletions. These factors were analyzed to estimate the present and future water resources baseline against which water availability for synfuels development and possible effects of synfuels development were measured. Except as otherwise noted, the Accelerated Case—2000 is the basis for the analysis that follows below. For this summary report, the assessment subarea findings are aggregated to the State level. The projected surface water flows have been adjusted for streamflow depletion by irrigation, electric generation, municipal and domestic water supplies, livestock, etc.

Wyoming—Projected surface flows of the Bighorn River will average about 2 million acre-feet annually in 2000. Typical low-flow conditions (7-day, 10-year flow) include the augmenting effects of Boysen and Buffalo Bill Reservoirs. Boysen Reservoir has Federal water available for contract pending completion of an Environmental Impact Statement and water availability studies by the U.S. Water and Power Resources Service. The legal availability of water in the Big Horn River may be influenced by future quantification of Federal Reserved and Indian water rights.

In the northeast section of Wyoming, the Powder and Tongue River Basins contain some of the richest coal reserves in the Upper Missouri assessment area. Surface water flows in the Powder and Tongue Rivers are projected to average about 500,000 acre-feet annually in 2000. Because existing low-flow conditions are near zero, use of available surface flows would require reservoir storage for both the Base and Accelerated Cases. Water requirements for the Accelerated Case would exceed the average annual flow by 10 percent and the dry year flow (80 percent exceedence level) by nearly 25 percent.

Groundwater is available in northeast Wyoming, but present information is insufficient to determine its full potential as a major water source. The availability of surface water in this area may be constrained by institutional provisions of the Belle Fourche River and Yellowstone River Compacts. The Accelerated Case could deplete streamflows to the maximum level for all projected uses allowed by provisions of the compacts. Quantification of Federal Reserved rights may further affect future availability of water.

Montana–Projected surface flows in the Upper Yellowstone River in 2000 will average over 5 million acre-feet annually. Typical low-flow conditions (7-day, 10-year) will exceed 0.5 million acre-feet per year. Synfuel development patterns by 2000 would deplete the Upper Yelowstone River by less than 1 percent of the average annual flow or about 2 percent of the low-flow condition. Conflicts with other offstream or instream uses would be minimal.

In the Lower Bighorn River, projected surface water flows will average over 2.4 million acre-feet annually in 2000. Low-flow conditions are generally enhanced to exceed 700,000 acre-feet per year by regulated releases at Yellowtail Reservior. The Yellowtail Reservoir has Federal water available for contract pending completion of an Environmental Impact Statement and water availability studies by the U.S. Water and Power Resources Service. The legal availability of water may be influenced by quantification of Federal Reserved and Indian water rights on the Bighorn River in both Montana and Wyoming.

Flows in the coal-rich Lower Powder and Tongue River Basins in Montana are affected by upstream depletions in Wyoming. Projected downstream surface water flows will average nearly 600,000 acre-feet annualy in 2000. Water requirements for the Accelerated case would exceed the average annual flow by 10 percent and the dry year flow by nearly 15 percent. In combination with the upstream synfuel water requirements in Wyoming, over 20 percent of the projected average annual downstream flow of the Powder and Tongue Rivers would be depleted. Over 25 percent of the dry year flow would be depleted for the same level of development. Because low-flow conditions are near zero, use of further surface water supplies for both the Base and Accelerated Case would require reservoir storage in Montana and Wyoming. Groundwater is also available in this area but information is insufficient to determine its full potential as a major source of water supply. Institutional considerations that may influence water availability include the Yellowstone River Compact and future quantification of Federal Reserved and Indian water rights.

The flows of the Lower Yellowstone River in Montana are also affected by aggregated upstream depletions for synfuel development. Projected surface flows in the Lower Yellowstone will average about 7.8 million acre-feet annually in 2000. Synthetic fuel development would deplete the lower basin average annual and dry year flows by less than 1 percent and less than 2 percent under low-flow conditions. In the entire Upper and Lower Yellowstone River Basin, the aggregated requirements of synfuel development under the Accelerated Case would be about 2 percent of the projected average annual downstream flow in 2000, nearly 3 percent of the dry year flow, or about 15 percent of low-flow conditions. Conflicts between instream uses and synthetic fuel development could arise under low-flow conditions. The legal status of available water supplies may be affected by quantification of Federal Reserved and Indian water rights. The recent reservation of over 6 million acre-feet per year of water by the State of Montana may also influence synfuel development potential in the Lower Yellowstone.

North and South Dakota.—By the year 2000, projected surface flows in the Upper Missouri River and tributaries will average about 15.8 million acre-feet annually in North Dakota and about 16.7 million acre-feet annually in South Dakota. Total water requirements for synthetic fuel development in both States would be less than 1 percent of average annual surface flows.

By 2000, the aggregated water depletions for synthetic fuel development for the Accelerated Case in the entire assessment area would be less than 2 percent of the average flow of the Missouri River in South Dakota.

Tributaries to the Missouri River in North and South Dakota will supply over 2 million acre-feed annually to the river. Some of these tributary waters could be developed for synthetic fueld supply. However, because of low-flow conditions in these tributaries, reservoir storage would be required.

- Water Supply Options

Existing single- and multiple-purpose water supply systems in the Upper Missouri River Basin would require major modification and expansion to provide water for regional synthetic fuel development and production.

In North and South Dakota, water for the hypothetical coal conversion development levels could be provided by diversions from the Missouri River. Water for coal conversion in North Dakota could be conveyed by an aqueduct system originating at Lake Sakakawea. In South Dakota, an aqueduct system could divert water from Lake Oahe.

For the Tongue and Powder River Basins, the assessment evaluated three hypothetical options for expanded surface water supplies to meet the demands of the two synfuel development cases. These three options were chosen because there was sufficient information to examine them at a broad conceptual level and to

estimate the order of magnitude of their costs and potential effects on the water resources. In addition to these three illustrations, however, there are other regional water supply options, including: development of groundwater supplies, conjunctive use of groundwater and surface water, conveyance of water from Lake Oahe to the Tongue and Powder River Basins, and water conservation. The assessment did not address groundwater as a regional supply alternative (either sole source or conjunctive use) because of data limitations. The conveyance of Lake Oahe water to the Tongue and Powder Basins as a single-purpose aqueduct serving only synfuel needs was deemed too expensive, and a multipurpose aqueduct from Lake Oahe was not assessed. Water conservation has been indirectly reflected in the water availability projections.

The three water supply options to supply surface water for synfuel development along the water-short Tongue and Powder River Basins of Montana and Wyoming are described briefly in the following sections. Their possible effects on water quantity, water quality, and environmental components and their estimated costs are listed as well. (Annual costs for the three options are based on construction, operation, and maintenance of aqueducts, pumping stations, terminal reservoirs and related appurtenances. Land costs are included also. Overall construction costs for the regional surface water supply systems could range from ½ to 1 billion dollars.) All three options assume that the recommendations for the Tongue and Moorhead Reservoirs (subarea 3) set forth in the Yellowstone Level B report will be implemented. The Water Resources Council does not recommend or support any of these water supply options; they are presented only to indicate possible implications of using various water sources for synfuel development. Actual selection of water sources must be based on more detailed studies.

Option 1.—Option 1 involves the development of streamflows near coal conversion plants with limited development of aqueducts, reservoirs, pumping stations, etc. (see Figure 3). The water provided under option 1 would use approximately 15,000 acre-feet per year of water that, according to the Yellowstone Level B Study, would already be committed for future irrigation. The rest of the water would come from uncommitted supplies. The estimated annual cost for option 1 would be $31 million for the Base Case and $38 million for the Accelerated Case.

The greatest streamflow depletion under water supply option 1 would be in the Powder River (see Table 6). By 2000, the average annual streamflow in the upper reach of the Powder River in Wyoming would be depleted by 12 percent for the Base Case and 27 percent for the Accelerated Case. In the lower reach of the Powder River in Montana, the streamflow would be depleted by 8 percent and 20 percent for the respective synfuel cases. Because low-flow conditions are already near zero, use of further surface water would require reservoir storage under both synfuel cases. Other streams in the assessment area would be depleted by an estimated 3 percent or less for the synfuel cases in 2000.

Surface water quality degradation from synfuel development could occur from runoff from the coal conversion facilities and from coal mining areas. Synfuel-related streamflow depletion may also contribute to downstream water quality degradation by reducing the volume of water available to dilute and assimilate wastes from other beneficial uses.

The TDS loading rates expected from runoff from synfuel facilities and associated mining and land reclamation areas were estimated to determine the effects on water quality. With the exception of the Knife and Cannonball Rivers in North Dakota, which already have high levels of TDS (about 1,000 mg/1 or more during average annual flows), the effects from assessed runoff would be negligible (increases less than 2 mg/1) under both Cases in 2000. However, the Accelerated Case in 2000 will increase TDS in the Knife River by 41 mg/1 and in the Cannonball River by 14 mg/1.

The Tongue, which presently has relatively low TDS in the upstream reaches, could be measurably affected (an increase of 14 mg/1) downstream by the year 2000 under the Accelerated Case.

There was not enough information to further assess degradation of water quality caused conjunctively by streamflow depletions from synfuels development and wastewater discharges by beneficial users. Option 1 suggests a measureable flow depletion of the Powder River and implicity the Tongue and suggests corresponding increases in TDS in these rivers in line with the depletions. Because other water uses are already projected to increase TDS in the Powder and the Tongue, any synfuel-related increases are important because of their compounding effect.

The U.S. Fish and Wildlife Service evaluated six selected stream reaches in Montana to assess what effect streamflow depletion from synfuel development could have on life stages of certain "target" fish. The stream reaches were evaluated for the three water supply options in the year 2000. The potential effects were measured by how much synfuel-related streamflow depletion would change a predetermined "weighted useable area" (i.e., an optimum relationship of stream depth to stream velocity for fish life cycles in a given stream reach).

Under option 1, the reaches of the Powder, Tongue, and Bighorn Rivers would sustain some habitat changes, but the overall quality ratings for fish habitat conditions would not significantly reduced by synfuel development.

Disturbances to land area and ecosystems were also estimated. For the Accelerated Case, construction of major water works considered under option 1 would disturb about 33,000 acres of land principally in grassland and cropland ecosystems. For the Base Case, option 1 would disturb about 11,000 acres.

Option 2.—Option 2 considers a major aqueduct to use water released from the Yellowtail Reservoir but diverted downstream on the Bighorn River in Montana (see Figure 4). The aqueduct system would extend to the Gillette, Wyoming, area. Water would also be released from this aqueduct to the Powder and Tongue Rivers to support coal conversion development along these river basins. Option 2 would use no committed water. The estimated annual cost for option 2 would be $38 million for the Base Case and $51 million for the Accelerated Case.

The greatest average annual streamflow depletion under water supply option 2 would be in the Bighorn River in Montana (see Table 7). Here the streamflow by 2000 would be depleted by approximately 2 percent for the Base Case and 5 percent for the Accelerated Case. Other streams would be depleted by about 3 percent or less for both synfuel cases.

Under water supply option 2, water quality degradation from increased TDS concentrations would be similar to that under option 1. Major rivers would be modestly depleted under the Base Case and Accelerated Case; therefore, TDS concentrations probably would not be increased substantially under this option.

Aquatic habitat affected by water supply option 2 generally would be limited to the Bighorn downstream from the Little Bighorn River confluence. Channel catfish would lose a small

percentage of their optimum spawning area, but the spawning area was estimated to be comparatively small even without synfuel development.

Water works constructed under option 2 for the Accelerated Case level of development would disturb about 34,000 acres of land primarily grassland and cropland. About 14,000 acres of land would be disturbed under the Base Case.

Option 3. —Option 3 considers a major aqueduct system to use water released from the Yellowtail Reservoir but diverted from the lower reach of the Yellowstone River in Montana (see Figure 5). This aqueduct system would also extend to the Gillette, Wyoming, area. Water would be released from this aqueduct to support synfuel development in the Powder and Tongue River Basins. Option 3 would use no committed water. The estimated annual cost for option 3 would be $42 million for the Base Case and $63 million for the Accelerated Case.

The greatest streamflow depletion under option 3 would be in the Cannonball River in North Dakota (see Table 8). For the Accelerated Case, the streamflow would be depleted by an estimated 3 percent. Other streams would be depleted an estimated 2 percent or less. Depletion would be 1 percent or less under the Base Case.

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Fig. 3—Surface Water Development—Option 1

(Base and Accelerated Cases - 2000)

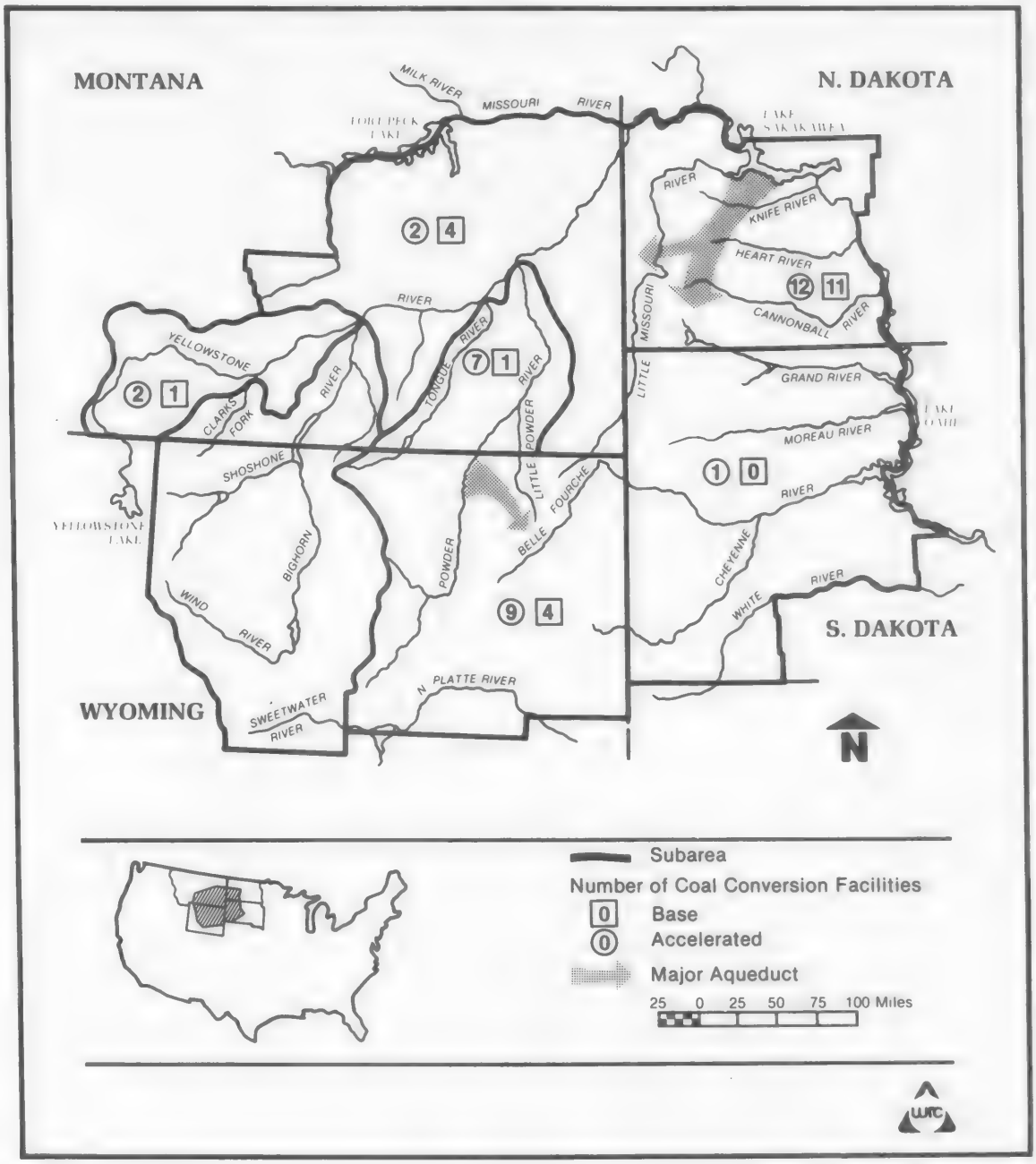

Table 6: Streamflows, Water Supply Option 1

Subarea	Stream and Location	Average Annual Streamflow (1000 ac-ft/yr) 1985	Average Annual Streamflow (1000 ac-ft/yr) 2000	Base Case Adjusted Streamflow (1000 ac-ft/yr) 2000	Base Case Percent[a/] Reduction	Accelerated Case Adjusted Streamflow (1000 ac-ft/yr) 1985	Accelerated Case Percent[a/] Reduction	Accelerated Case Adjusted Streamflow (1000 ac-ft/yr) 2000	Accelerated Case Percent[a/] Reduction
1	Yellowstone River at Huntley, MT	5,531	5,456	5,449	0.1	5,531	0	5,442	0.3
2	Bighorn River at Bighorn, MT	2,597	2,431	2,407	1.0	2,588	0.3	2,377	2.2
3	Powder River at Locate, MT	393	343	315	8.2	393	0	276	19.5
4	Missouri River near Culbertson, MT	7,774	7,774	7,755	0.2	7,774	0	7,755	0.2
	Yellowstone River near Sidney, MT	8,429	7,840	7,781	0.8	8,420	0.1	7,697	1.8
5	Cannonball River at Breien, ND	181	180	180	0	181	0	174	3.3
	Missouri River near Schmidt, ND	15,872	15,772	15,561	1.3	15,784	0.6	15,472	1.9
7	Powder River at Arvada, WY	169	166	146	12.0	169	0	122	26.5
8	Missouri River at Pierre, SD	17,042	16,662	16,451	1.3	16,954	0.5	16,362	1.8

[a/] $$\text{Percent reduction} = \frac{\text{average annual streamflow} - \text{adjusted streamflow}}{\text{average annual streamflow}} \times 100$$

Fig. 4—Surface Water Development—Option 2

(Base and Accelerated Cases - 2000)

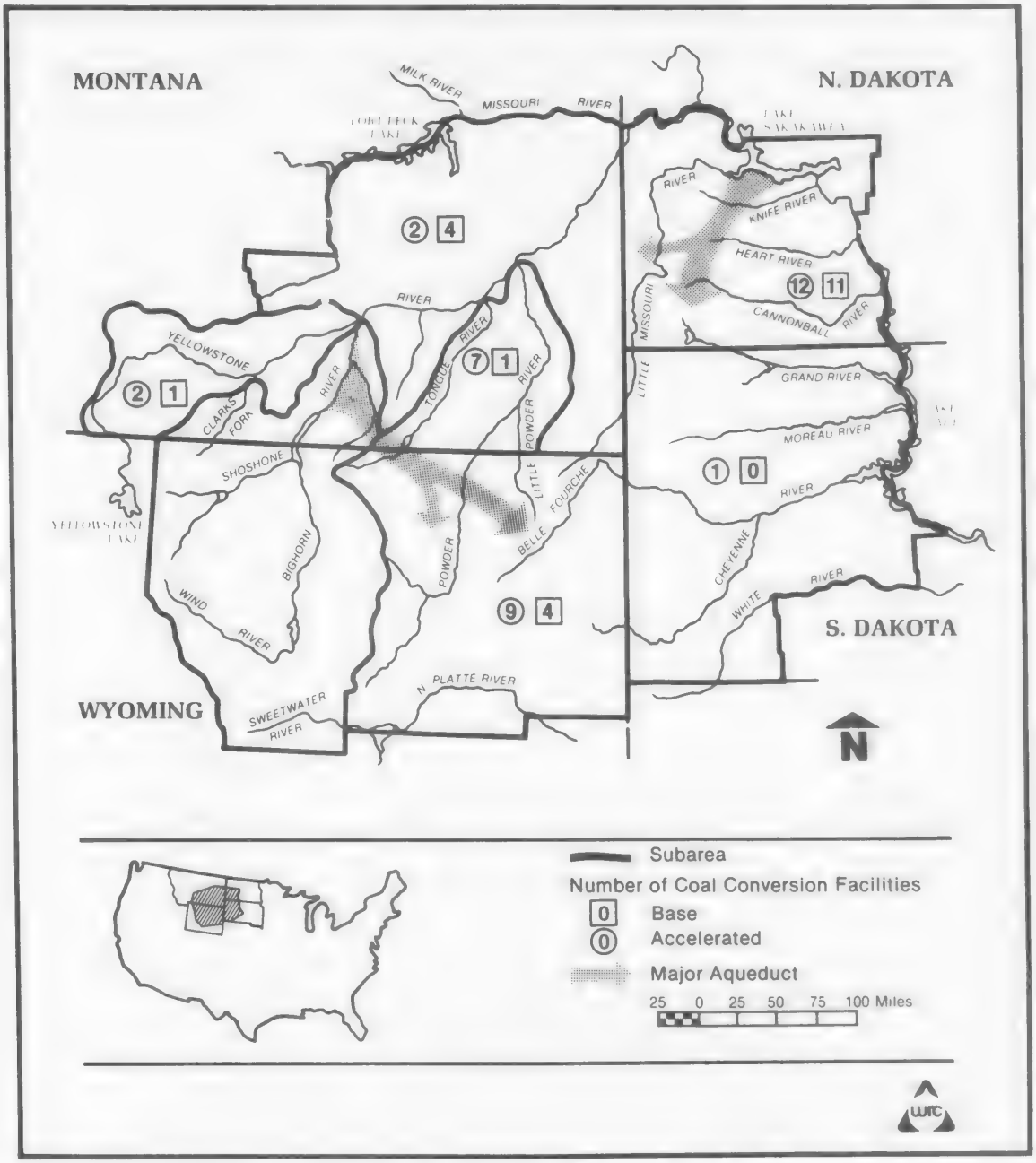

Table 7: Streamflows, Water Supply Option 2

Subarea	Stream and Location	Average Annual Streamflow (1000 ac-ft/yr) 1985	Average Annual Streamflow (1000 ac-ft/yr) 2000	Base Case Adjusted Streamflow (1000 ac-ft/yr) 2000	Base Case Percent[a/] Reduction	Accelerated Case Adjusted Streamflow (1000 ac-ft/yr) 1985	Accelerated Case Percent[a/] Reduction	Accelerated Case Adjusted Streamflow (1000 ac-ft/yr) 2000	Accelerated Case Percent[a/] Reduction
1	Yellowstone River at Huntley, MT	5,531	5,456	5,449	0.1	5,531	0	5,442	0.3
2	Bighorn River at Bighorn, MT	2,597	2,431	2,379	2.1	2,588	0.3	2,310	5.0
3	Powder River at Locate, MT	393	343	343	0	393	0	343	0
4	Missouri River near Culbertson, MT	7,774	7,774	7,755	0.2	7,774	0	7,755	0.2
	Yellowstone River near Sidney, MT	8,429	7,840	7,781	0.8	8,420	0.1	7,697	1.8
5	Cannonball River at Breien, ND	181	180	180	0	181	0	174	3.3
	Missouri River near Schmidt, ND	15,872	15,772	15,561	1.3	15,784	0.6	15,472	1.9
7	Powder River at Arvada, WY	169	166	166	0	169	0	166	0
8	Missouri River at Pierre, SD	17,042	16,662	16,451	1.3	16,954	0.5	16,362	1.8

[a/] $$\text{Percent reduction} = \frac{\text{average annual streamflow} - \text{adjusted streamflow}}{\text{average annual streamflow}} \times 100$$

Fig. 5—Surface Water Development—Option 3

(Base and Accelerated Cases - 2000)

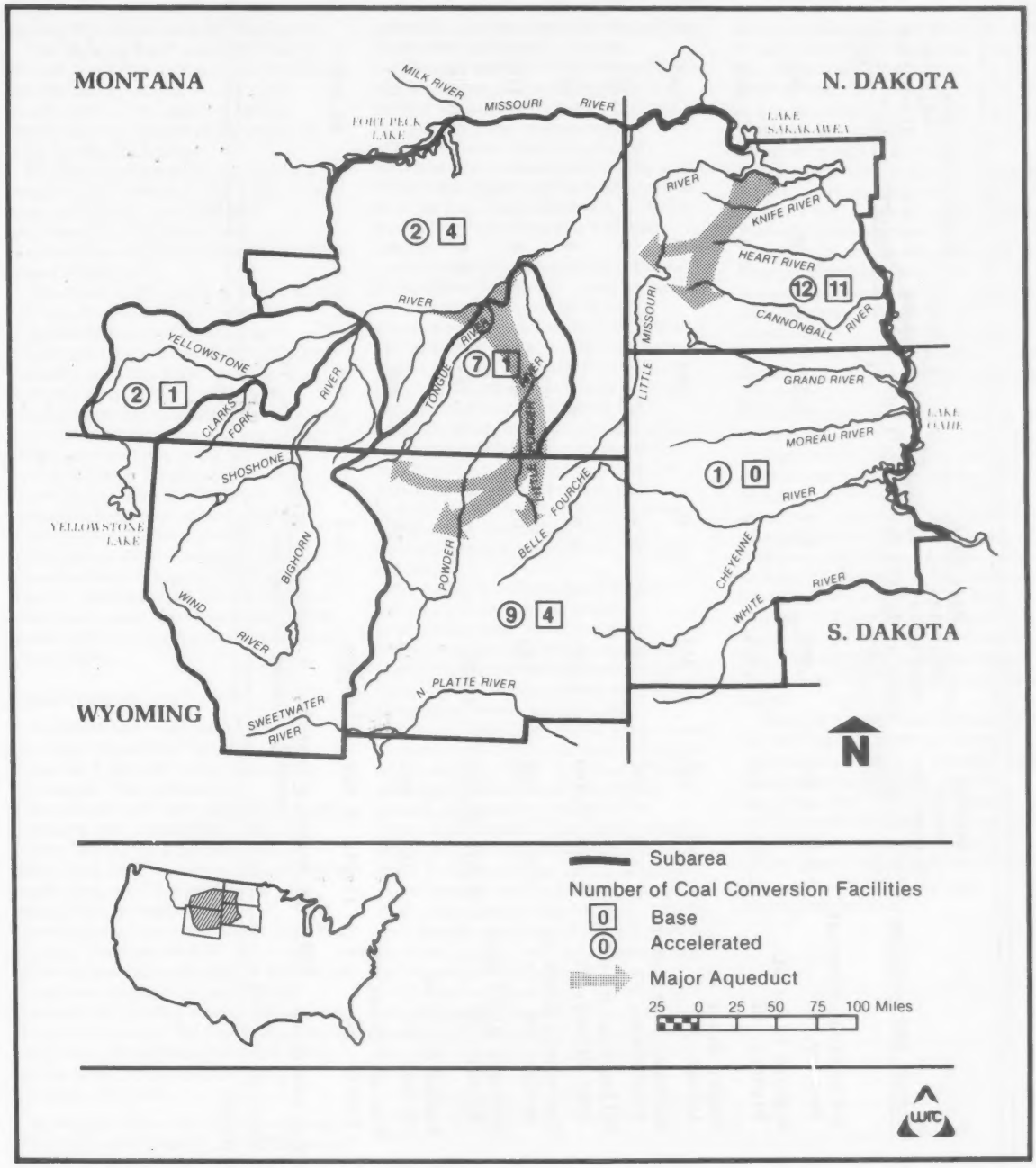

Table 8: Streamflows, Water Supply Option 3

Subarea	Stream and Location	Average Annual Streamflow (1000 ac-ft/yr) 1985	Average Annual Streamflow (1000 ac-ft/yr) 2000	Base Case Adjusted Streamflow (1000 ac-ft/yr) 2000	Base Case Percent[a/] Reduction	Accelerated Case Adjusted Streamflow (1000 ac-ft/yr) 1985	Accelerated Case Percent[a/] Reduction	Accelerated Case Adjusted Streamflow (1000 ac-ft/yr) 2000	Accelerated Case Percent[a/] Reduction
1	Yellowstone River at Huntley, MT	5,531	5,456	5,449	0.1	5,531	0	5,442	0.3
2	Bighorn River at Bighorn, MT	2,597	2,431	2,431	0	2,588	0.3	2,430	0.1
3	Powder River at Locate, MT	393	343	343	0	393	0	343	0
4	Missouri River near Culbertson, MT	7,774	7,774	7,755	0.2	7,774	0	7,755	0.2
	Yellowstone River near Sidney, MT	8,429	7,840	7,781	0.8	8,420	0.1	7,697	1.8
5	Cannonball River at Breien, ND	181	180	180	0	181	0	174	3.3
	Missouri River near Schmidt, ND	15,872	15,772	15,561	1.3	15,784	0.6	15,472	1.9
7	Powder River at Arvada, WY	169	166	166	0	169	0	166	0
8	Missouri River at Pierre, SD	17,042	16,662	16,451	1.3	16,954	0.5	16,362	1.8

[a/] Percent reduction = $\frac{\text{average annual streamflow} - \text{adjusted streamflow}}{\text{average annual streamflow}} \times 100$

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Under option 3, water quality degradation from increased TDS concentrations would be similar to that under option 1. Major rivers would be modestly depleted under the Base Case and Accelerated Case; therefore, TDS concentrations probably would not be increased substantially by this option.

The Bighorn River would be the major stream reach in which aquatic life would be affected by option 3. Under the Accelerated Case, channel catfish would lose 40 percent of the optimum area for the adult stage.

For the Accelerated Case, option 3 would disturb about 37,000 acres of land area, principally cropland and grassland. For the Base Case, construction of option 3 would disturb about 16,000 acres.

The three illustrations of water supply options described above represent possible choices for developing additional water for synfuel facilities. Actually securing water supplies for synfuels development will require careful planning to ensure that offstream and instream requirements are satisfied. Water use conflicts will probably arise in the coal-rich Tongue and Powder River Basins. Key institutional considerations in planning include existing State water rights, the Yellowstone River Compact, the Belle Fourche River Compact, the North Platte Decree, instream flow needs, Missouri main stem reservoir operations, Indian water rights, and other Federal reserved water rights.

Other Findings

Groundwater. —Groundwater is abundant in parts of the assessment area, but it has not been extensively developed. The hydrologic characteristics of most aquifers are not presently well understood. The Fort Union Group, the principal aquifer underlying coal resources in much of the study area, would appear most susceptible to degradation (e.g., percolation of dissolved solids from coal mining). On a regionwide basis, the effect on groundwater quality should not be serious through the year 2000 because coal mining would disturb less than 0.2 percent of the Fort Union Group land area. Groundwater in local areas, on the other hand, could be more seriously affected.

Runoff and Process Water. —At each coal conversion facility, runoff from coal yards and wastewater from coal conversion processes and cooling water blowdown will require treatment.

Estimated construction costs (1979) for runoff treatment and disposal for a unit size facility would range from $4 to $6 million. Annual operating cost is estimated at $100,000.

For unit size facilities, high Btu coal gasification would have the highest estimated costs (1979) for treatment facility construction ($20 million) and for operation and maintenance ($4 million). Treatment facilities for low Btu gasification and liquefaction would have similar, although lower, costs—$15 million for construction and $2–3 million for operation and maintenance.

Treated wastewater from coal conversion processes and cooling water blowdown would not be discharged to streams (i.e., "zero discharge"). Water would be recycled within a closed system.

Hydroelectric Power Generation.— Streamflow depletion caused by coal conversion development in the assessment area would reduce future hydroelectric power generation by less than 1 percent. Hydroelectric power generated upstream at the Boysen and Yellowtail Reservoirs would not be affected. Siting of concentrated, water-depleting developments in the upper reaches of the Missouri River and its tributaries would affect regional hydroelectric power generation more significantly than siting similar developments nearer the downstream reaches.

Navigation.—There is no major commercial navigation in the assessment area. Assessed coal conversion developments would have negligible effects on streamflows for barge tow traffic downstream of Sioux City, Iowa, where commercial navigation begins on the Missouri River.

Community Infrastructure.—Because of the strongly rural character of the assessment area, rapid population growth attendant on synfuel development could significantly impact the infrastructure of communities. By 2000, the hypothetical levels of synfuel development could increase population in the assessment area between 100,000 and 160,000 persons. Advanced planning by State, county, and local governments in conjunction with the synfuel industries could mitigate some of the socioeconomic demands. Projected tax revenues from the hypothetical synthetic fuel development and coal mining in Montana, Wyoming, and North Dakota would appear to be adequate for coping with the attendant increase in social costs.

Conclusion

Surface water is generally available in the Upper Missouri River Basin to support coal conversion development. Regional availability of groundwater can only be assessed by further field studies.

Approximately 700,000 acre-feet of surface water are available annually in the Boysen and Yellowtail Reservoirs on the Bighorn River, pending completion of environmental impact statement and water availability studies by the U.S. Water and Power Resources Service. Not all synfuel development would be located near this water supply, however.

Existing single- and multiple-purpose water supply systems in the Upper Missouri would require major modification and expansion to enable the use of available water supplies for regional coal conversion development. Possible considerations to provide water at desired plant locations include new storage, interbasin transfers, changes in present water use, and groundwater development. The operations of some reservoirs in the Yellowstone River Basin may need to be altered to assure sufficient flows for energy needs during dry years.

The time lag between planning and implementing water supply systems may be 20 years or more. Critical subbasins, such as the Tongue and Powder River, will require further detailed studies to determine what water management alternatives best serve the needs of instream and offstream users. Inherent in these studies will be an emphasis on existing State water rights, River Compacts, Court Decrees, instream flow reservations, Missouri River main stem reservoir operations, Indian water rights, and other Federal reserved water rights.

There is a need now for a unified commitment by Federal, State, local, and private entities to advance water resources planning management strategies that will ensure that water will be available for energy technology development and other beneficial uses in the Upper Missouri River Basin.

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